



# **MARKSCHEME**

**May 2012**

**CHEMISTRY**

**Higher Level**

**Paper 2**

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## General Marking Instructions

*Assistant Examiners (AEs) will be contacted by their team leader (TL) through Scoris™, by e-mail or telephone – if through Scoris™ or by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through Scoris™ or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of Scoris™, please contact [emarking@ibo.org](mailto:emarking@ibo.org).*

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1. Follow the markscheme provided, award only whole marks and mark only in **RED**.
2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.
3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**
4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use Scoris™ annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.
5. Personal codes/notations are unacceptable.
6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, enter a zero in the mark panel on the right-hand side of the screen. Where an answer to a part question is worth no marks because the candidate has not attempted the part question, enter an “NR” in the mark panel on the right-hand side of the screen.
7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. Scoris™ will only award the highest mark or marks in line with the rubric.
8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp ‘seen’ on any page that contains no other annotation.
9. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the “CON” stamp.

## Subject Details: Chemistry HL Paper 2 Markscheme

### Mark Allocation

Candidates are required to answer **ALL** questions in Section A [**40 marks**] and **TWO** questions in Section B [**2 x 25 marks**]. Maximum total = [**90 marks**].

1. A markscheme often has more marking points than the total allows. This is intentional.
2. Each marking point has a separate line and the end is shown by means of a semicolon (;).
3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.
4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.
5. Words that are underlined are essential for the mark.
6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.
7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect).
8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.
11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme, similarly, if the formula is specifically asked for, unless directed otherwise in the markscheme do not award a mark for a correct name.
12. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.
13. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

**SECTION A**

1. (a) (i) bromine/ $\text{Br}_2$ ; [1]  
*Do not allow Br or bromide/ $\text{Br}^-$ .*
- (ii)  $7.9 \times 10^{-5} (\text{mol dm}^{-3} \text{ s}^{-1})$ ;  
*The number of significant figures must be correct.*  
*Allow  $8.0 \times 10^{-5} (\text{mol dm}^{-3} \text{ s}^{-1})$ .*
- (only 2 significant figures) because of precision of time/ $[\text{Br}_2]$  measurements; [2]  
*Allow answers based on rate laws or orders of reaction.*  
*M2 can only be scored if M1 correct.*
- (iii)  $[\text{Br}_2]$ : 1% **and** Time: 0.8%;  
 Percentage Uncertainty: 1.8%; [2]  
 Accept Percentage Uncertainty: 2%.  
*Do not allow answers based on rate laws or orders of reaction.*
- (b) (i)  $\text{CH}_3\text{COCH}_3$ : 1;  
 $\text{Br}_2$ : 0;  
 $\text{H}^+$ : 1; [3]
- (ii)  $\text{rate} = k [\text{H}^+] [\text{CH}_3\text{COCH}_3]$ ;  
 $k = 4.00 \times 10^{-3}$ ;  
 $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ ; [3]
- (c) (no it doesn't) actual reaction is zero order with respect to  $\text{Br}_2$ ;  
 (no it doesn't) actual rate determining step/slow step does not involve  $\text{Br}_2$  / OWTTE;
- OR**
- (no it doesn't) reaction is first order with respect to  $\text{H}^+$ ;  
 (no it doesn't) mechanism/rate determining step/slow step does not involve  $\text{H}^+$  / OWTTE;
- OR**
- (no it doesn't) reaction is first order with respect to  $\text{CH}_3\text{COCH}_3$ ;  
 (no it doesn't) rate determining step/slow step does not involve  $\text{CH}_3\text{COCH}_3$  / OWTTE; [2]
- Award no marks if yes stated.*

2. (a) (i)  $n(\text{Pb}): \left( \frac{64.052}{207.19} \right) = 0.30915 \text{ (mol)}$

$n(\text{C}): \left( \frac{29.703}{12.01} \right) = 2.473 \text{ (mol)}$

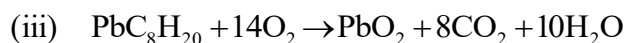
$n(\text{H}): \left( \frac{6.245}{1.01} \right) = 6.18 \text{ (mol)}$

*Do not penalize if integer values of atomic masses used.*

*Accept alternative calculation method.*

*Award [2] for three correct.*

*Award [1] for any two correct.*



correct reactants and products;

correct coefficients;

*M2 can only be scored if M1 correct.*

[2]

(b) *Local pollutant:*

carbon monoxide/CO / volatile organics/VOCs / nitrogen oxide/NO / (unburnt) hydrocarbons;

*Do not accept methane/CH<sub>4</sub>, ethane/C<sub>2</sub>H<sub>6</sub>, propane/C<sub>3</sub>H<sub>8</sub> or butane/C<sub>4</sub>H<sub>10</sub>.*

*Global pollutant:*

nitrogen oxide/NO / carbon dioxide/CO<sub>2</sub>;

*Accept nitrogen dioxide/NO<sub>2</sub> / NO<sub>x</sub> for both local or global pollutant.*

*Accept other widely used names for NO such as nitric oxide/nitrogen monoxide/nitrogen(II) oxide or nitrogen(IV) oxide for NO<sub>2</sub>.*

[2]

3. (a) (carbon to carbon) double bond / alkene;  
*Accept if identified on diagram.*

orange/brown/red/yellow to colourless / bromine is decolourized; [2]  
*M2 can be only scored if M1 correct.*

- (b) (i)  $\text{COOH}/\text{CO}_2\text{H}$  / carboxylic acid / alkanoic acid; [1]  
*Do not allow carboxylic/alkanoic, carbonyl or carboxylate.*

(ii) redox / oxidation (of alcohol); [1]

- (c) (i) aldehyde / alkanal /  $\text{CHO}$ ; [1]  
*Accept  $\text{C}=\text{O}$  / carbonyl.*

- (ii)  $\text{Z} < \text{X} < \text{Y}$ ;  
*Accept  $\text{Z}, \text{X}, \text{Y}$  or  $\text{ZXY}$ .*

no hydrogen bonding in **Z** / hydrogen bonding in **X and Y**;  
*Accept statements such as **Z** has only van der Waals/London/dispersion forces **and** dipole-dipole forces.*

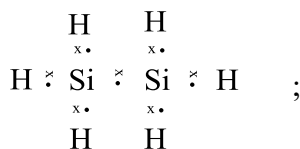
**Y** most polar / more electrons / forms dimers / forms two hydrogen bonds /  
greater molecular/molar mass; [3]  
*Do not accept **Y** has a larger mass.*



4. (a)  $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-}$  ;  
 Fe/iron; [2]  
*Do not accept Fe/Fe<sup>2+</sup> half-equation or Fe<sup>2+</sup>.*
- (b)  $\text{Mg(s)} + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Fe(s)}$  ; [1]
- (c) (i) (potential of reduction half-reaction) under standard conditions measured relative to standard hydrogen electrode/SHE / difference of standard reduction potential of substance undergoing reduction and standard reduction potential of substance undergoing oxidation / *OWTTE*; [1]
- (ii) (+)1.92 (V); [1]
- (d) (i) *S*:  $2\text{H}_2\text{O(l)} + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$  /  $2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$  ;  
*T*:  $2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^{-}$  ; [2]
- (ii) 1:1; [1]
- (iii) increase in current/voltage/surface area of electrodes; [1]
- (iv) oxygen;  
 $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^{+} + 4\text{e}^{-}$  /  $4\text{OH}^{-} \rightarrow 2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^{-}$ ; [2]

## SECTION B

5. (a) (i)



[1]

*Accept any combination of lines, dots or crosses to represent electron pairs.*

(ii)  $109^\circ$  /  $109.5^\circ$  /  $109^\circ 28'$ ;

four/tetrahedrally arranged negative charge centres/electron domains/electron pairs (around central/silicon atom) / equal repulsion between bonding pairs (around central/silicon atom) / *OWTTE*;

[2]

*M2 is an independent marking point.*

*Reference must be made to negative or electron.*

*Do not accept tetrahedral molecule.*

(iii)  $sp^3$ ;

[1]

(iv) C–H;

larger difference in electronegativity (for C–H bond) / smaller difference in electronegativity (for Si–H bond) /  $\Delta EN$  (CH) = 0.4 **and**  $\Delta EN$  (SiH) = 0.3;

[2]

(v) both (molecules) non-polar;

both (molecules) symmetrical / polar bond effects cancel out / *OWTTE*;

[2]

(vi) stronger/larger/greater van der Waals'/London/dispersion forces;

*Do not accept stronger/larger/greater intermolecular forces.*

more electrons / stronger instantaneous dipole;

[2]

*Do not accept larger mass.*

(b) (i)  $(\sum \ddot{H}_f^\circ (\text{products}) = ) -5360 \text{ (kJ)};$

$(\sum \ddot{H}_f^\circ (\text{reactants}) = ) +160 \text{ (kJ)};$

$= -5520 \text{ (kJ)};$

[3]

(ii)  $(-1560 \times 2 =) -3120 \text{ (kJ)};$

[1]

(iii) *Structure:*

CO<sub>2</sub> molecular **and** SiO<sub>2</sub> three-dimensional/network/giant lattice/giant covalent/macromolecular/repeating tetrahedral units;

CO<sub>2</sub> linear **and** SiO<sub>2</sub> tetrahedral;

*Intramolecular Bonding:*

covalent bonds in CO<sub>2</sub> **and** SiO<sub>2</sub>;

double bonds in CO<sub>2</sub> **and** single bonds in SiO<sub>2</sub>;

[3 max]

*Accept diagrams showing bonding types (double and single) within the structures.*

- (c) *Bonds broken:*  
 $6\text{Si-H}, \text{Si-Si}, \text{H-H} / (+)2570 \text{ (kJ)};$   
*Bonds formed:*  
 $8\text{Si-H} / (-)2544 \text{ (kJ)};$   
 $+26 \text{ (kJ)};$

**OR**

- Bonds broken:*  
 $\text{Si-Si}, \text{H-H} / (+)662 \text{ (kJ)};$   
*Bonds formed:*  
 $2\text{Si-H} / (-)636 \text{ (kJ)};$   
 $+26 \text{ (kJ)};$

[3]

- (d) (i) 1 to 3;  
*Accept any answer in this range:  $\text{pH} \leq 3$ .*

HCl/strong acid formed;  
 $\text{SiCl}_4(\text{l}) + 4\text{H}_2\text{O}(\text{l}) \rightarrow \text{Si}(\text{OH})_4(\text{s}) + 4\text{HCl}(\text{aq}) ;$

[3]

- (ii) *Aqueous solution:*  
 mobile ions/charged particles present;

*Liquid:*  
 molecular covalent / no (mobile) charged particles/ions;

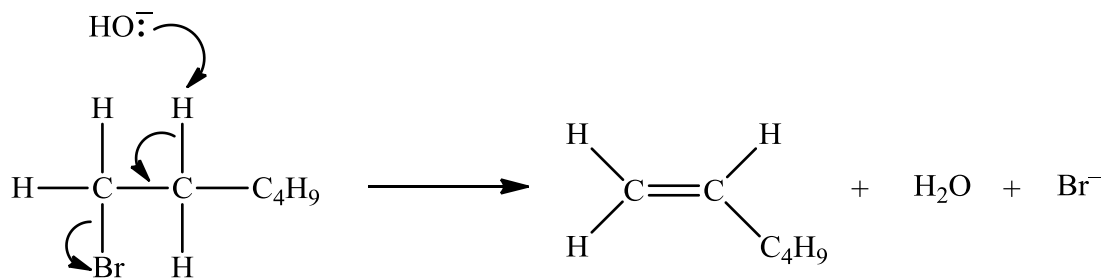
[2]

6. (a)  $\text{Br}_2(\text{g}) \rightleftharpoons \text{Br}_2(\text{l})$  ;  
 $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{HBr}(\text{g})$  ; [2]
- (b) (i) increase volume of liquid / no change of colour of vapour; [1]  
(ii) shifts to right/toward products/forward reaction favoured; [1]  
*Accept reverse statement if process written the other way around.*  
*Answer must match stated equation.*  
(iii) no effect;  
same amounts/number of (gaseous) moles/molecules on both sides; [2]
- (c) (i)  $(K_c =) \frac{[\text{HBr}]^2}{[\text{H}_2][\text{Br}_2]}$  ; [1]  
(ii) no effect (only depends on the temperature); [1]
- (d) (i) *Strong acid:* acid/electrolyte (assumed to be almost) 100%/completely dissociated/ionized (in solution/water) / *OWTTE and Weak acid:* acid/electrolyte only partially/slightly dissociated/ionized (in solution/water) / *OWTTE*;  
 $\text{HBr}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Br}^-(\text{aq})$  ;  
 $\text{HF}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{F}^-(\text{aq})$  ; [3]
- (ii) *Data points:*  
(0.00, 2.88) **and** (12.50, 4.77);  
*For first point also accept volume = 0.00 with pH in range 2.8–2.9.*  
*For second point also accept either:*  
*volume in range between 12.5–12.6 and pH 4.8–4.9*  
**OR**  
*volume in range between 25.0–25.2 and pH 8.0–10.0*  
*For (0.00, 2.88):*  
 $[\text{H}^+] = [\text{F}^-]$  ;  
 $\text{p}K_a = 2\text{pH} - 1 / K_a = \frac{[\text{H}^+]^2}{0.100}$  ;  
*For (12.50, 4.77):*  
 $[\text{HF}] = [\text{F}^-]$  ;  
 $\text{p}K_a = \text{pH}$  ;  
 $\text{p}K_a = 4.77$  ; [6]  
*Accept any value in range 4.7–4.9 if consistent with data points.*  
*Accept alternative calculation method if other data points from the table or graph are used and the  $\text{p}K_a$  in correct range.*
- (iii) bromothymol blue / phenol red / phenolphthalein;  
 $\text{p}K_a$ /end point of indicator in range 7–10 as pH at equivalence in range 7–10; [2]

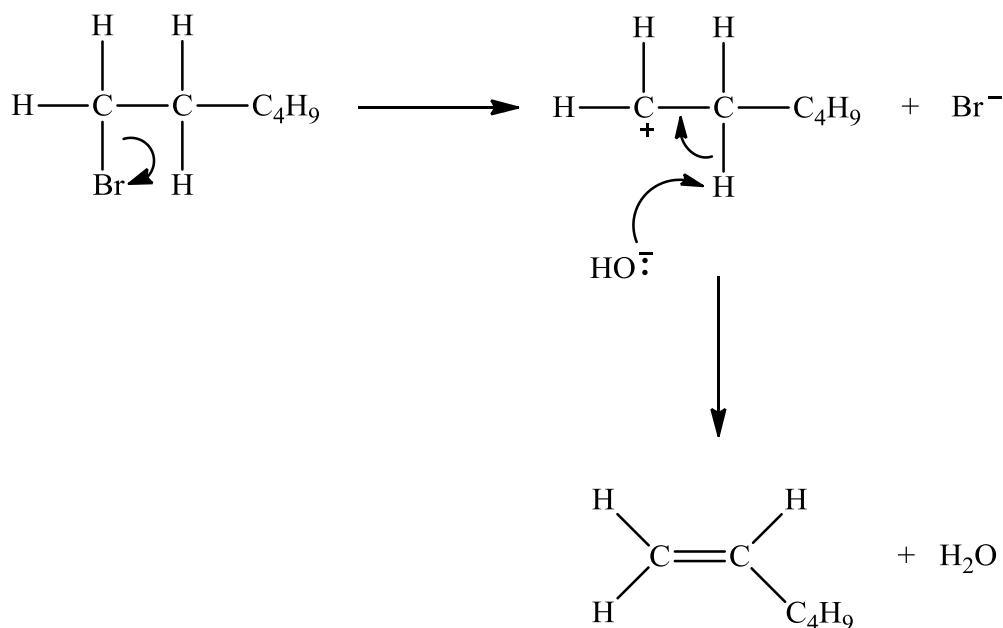
- (e) (i)  $Br_2$ : 0  
 $HBr$ : -1  
 $HOBr$ : +1 [2]  
*Award [2] for three correct.*  
*Award [1] for any two correct.*
- (ii) bromine is oxidized **and** reduced / disproportionation; [1]
- (iii)  $K_c < 1$ ; [1]
- (f) (i)  $F_2$ /fluorine; [1]  
*Do not allow F.*
- (ii)  $50 \text{ (cm}^3\text{)} / 0.050 \text{ dm}^3$ ; [1]

7. (a) (i) molar mass =  $102.20 \text{ (g mol}^{-1}\text{)}$ ;  
amount  $(= \frac{5.00}{102.20}) = 0.0489 \text{ (mol)}$ ; [2]
- (ii) theoretical yield =  $(84.18 \times 0.0489 =) 4.12 \text{ (g)}$ ;  
percentage yield  $= \left( \frac{2.62}{4.12} \times 100 = \right) 63.6 \%$ ; [2]  
*Accept alternative calculation method.*
- (iii) yield above 100% not possible / experimental yield > theoretical yield / *OWTTE*;  
*Must have reference to a final yield.*
- sample contaminated with hexan-1-ol/water / inadequate drying / *OWTTE*; [2]  
*Do not accept error in reading balance/weighing scale.*

(b)



OR

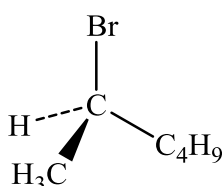
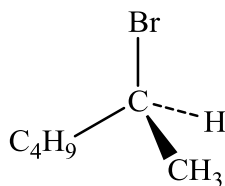


curly arrow going from lone pair/negative charge on O in  $\text{HO}^-$  to H on  $\beta\text{-C}$ ;  
*Do not allow curly arrow originating on H in  $\text{HO}^-$ .*

curly arrow going from CH bond to form C=C bond;  
 curly arrow showing Br leaving;  
 formation of organic product  $\text{H}_2\text{C}=\text{CH}(\text{C}_4\text{H}_9)$  **and**  $\text{H}_2\text{O}$  **and**  $\text{Br}^-$ ;

[4]

(c) (i)



[2]

- (ii) use a polarimeter / polarimetry;  
isomers rotate plane of polarized light in equal, but opposite directions;

[2]

(d) geometric / cis-trans / E-Z;

[1]

- (e) (i) 2-methylpentane;  
3-methylpentane;  
2,2-dimethylbutane;  
2,3-dimethylbutane;

[3 max]

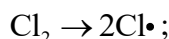
- (ii) hexane;  
*Accept the molecular structure, full structural formula or condensed structural formula.*

straight chain/no branches, hence increased surface area/more closely packed;  
stronger/larger/greater London/dispersion/van der Waals';  
*Accept the opposite arguments.*

[3]

*Do not accept stronger/larger/greater intermolecular forces.*

(f) *Initiation:*



*Essential condition:*

UV/sunlight/hf/hv;

*Propagation:*



*Termination:*



[4]

*Allow more specific detail of R based on hexane (e.g.  $\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{-H}$ ) in mechanistic steps.*

8. (a) (i) ionization, acceleration, deflection/separation  
*Award [1] for all three names and [1] for correct order.*  
*Award [1] for two names in correct order.*
- Ionization:*  
 sample bombarded with (high-energy/high-speed) electrons / OWTTE;  
*Acceleration:*  
 electric field/oppositely charged plates;  
*Deflection:*  
 (electro)magnet/magnetic field; [5]
- (ii) ratio of average/mean mass of an atom to the mass of C-12 isotope /  
 average/mean mass of an atom on a scale where one atom of C-12 has a  
 mass of 12 / sum of the weighted average/mean mass of isotopes of an  
 element compared to C-12 / OWTTE; [1]  
*Award no mark if “element” is used instead of “atom”.*
- (iii)  $A_r = \frac{(46 \times 13.5) + (47 \times 7.4) + (48 \times 73.7) + (49 \times 5.4)}{100}$ ;  
 47.7; [2]  
*Accept atomic mass units but award [1 max] if other units given.*  
*Answer must be given to one decimal place.*
- (iv) prevents collisions/unintentional deflections / OWTTE; [1]
- (b) (i)  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$ ;  
 4s; [2]
- (ii) 4<sup>th</sup> electron removed from 3d **and** 5<sup>th</sup> electron removed from 3p;  
 10<sup>th</sup> electron removed from 3p **and** 11<sup>th</sup> electron removed from 3s;  
*Accept either of the following answers for the third mark:*  
 electrons removed from lower energy level / energy level closer to nucleus  
 are attracted more strongly;  
 greater effective nuclear charge / s electrons more penetrating; [3 max]
- (iii) +2, +3, +4; [1]
- (iv) (colour) due to partially filled/incomplete d sub-level/orbital;  
 d sub-level is split / d orbitals are split;  
 $Ni^{2+}(aq)$  has incomplete 3d sub-level/orbital but  $Sc^{3+}(aq)$  has no 3d  
 electron/empty/d sub-level;  
 electrons move from lower to higher (sub)levels when they absorb  
 energy/light;  
 $Ni^{2+}(aq)$  (appears green because it) absorbs red; [5]



- (c) (i) line spectrum;  
 (lines) converge at high energy/frequency/shorter wave length/blue end of spectrum; [2]  
*Both marks can be awarded if suitable diagram is given.*
- (ii) electron transition from higher to lower/second energy levels;  
 each transition causes emission of light of specific frequency/wavelength/  
 energy;  
 each transition/line is related to energy difference /  $\Delta E = \frac{hf}{\lambda} / \frac{h\nu}{\lambda} / \frac{hc}{\lambda}$ ;  
 energy levels in hydrogen atom are closer/converge at higher energy; [3 max]
-